

Technical Report Documentation Page

1. Report No. FHWA/VA-88/22	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Signal Timing Optimization - A Review of State Programs		5. Report Date April 1988	
7. Author(s) E. D. Arnold, Jr.		6. Performing Organization Code 8. Performing Organization Report No. VTRC 88-R22	
9. Performing Organization Name and Address Va. Transportation Research Council Box 3817 University Station Charlottesville, VA 22903		10. Work Unit No. (TRIS)	
12. Sponsoring Agency Name and Address Virginia Department of Transportation 1401 E. Broad Street Richmond, VA 23219		11. Contract or Grant No. 2398	
15. Supplementary Notes In cooperation with the U.S. Department of Transportation, Federal Highway Administration		13. Type of Report and Period Covered Final Report Nov. 1987 - Mar. 1988	
14. Sponsoring Agency Code		16. Abstract In early 1988 the Virginia Department of Transportation (VDOT) was awarded a grant of \$3.8 million from the Exxon oil overcharge refund to implement a statewide signal timing optimization program. A limited survey of signal timing programs in other states was undertaken to assist the VDOT in decisions regarding the design of its program. The findings from that survey are reported in this document.	
17. Key Words signal timing optimization; retiming		18. Distribution Statement No restrictions. This document is available to the public through the NTIS, Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 35	22. Price

SIGNAL TIMING OPTIMIZATION

A Review of State Programs

by

E. D. Arnold, Jr.
Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia
Department of Transportation and
the University of Virginia)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

April 1988
VTRC 88-R22

TRAFFIC RESEARCH ADVISORY COMMITTEE

- A. L. THOMAS, JR., Chairman, State Traffic Engineer, VDOT
- J. B. DIAMOND, District Traffic Engineer, VDOT
- C. F. GEE, Assistant Construction Engineer, VDOT
- T. A. JENNINGS, Safety/Technology Transfer Coordinator, FHWA
- C. O. LEIGH, Maintenance Engineer, VDOT
- T. W. NEAL, JR., Chemistry Laboratory Supervisor, VDOT
- W. C. NELSON, JR., Assistant State Traffic Engineer, VDOT
- H. E. PATTERSON, Senior Traffic Engineer, City of Norfolk
- R. L. PERRY, Assistant Transportation Planning Engineer, VDOT
- F. D. SHEPARD, Research Scientist, VTRC
- L. C. TAYLOR II, District Traffic Engineer, VDOT

TABLE OF CONTENTS

	<u>Page</u>
Abstract.....	v
Introduction.....	1
Scope of Survey.....	1
Summary of Findings.....	2
Types of Programs.....	2
Source of Funds.....	3
Eligible Expenditures.....	3
Targeted Intersections.....	4
Evaluation Procedures.....	5
Results.....	5
Appendix A: California.....	7
Appendix B: Florida.....	13
Appendix C: Illinois.....	17
Appendix D: Maryland.....	21
Appendix E: Michigan.....	23
Appendix F: Missouri.....	25
Appendix G: North Carolina.....	27
Appendix H: Wisconsin.....	29

ABSTRACT

In early 1988 the Virginia Department of Transportation (VDOT) was awarded a grant of \$3.8 million from the Exxon oil overcharge refund to implement a statewide signal timing optimization program. A limited survey of signal timing programs in other states was undertaken to assist the VDOT in decisions regarding the design of its program. The findings from that survey are reported in this document.

SIGNAL TIMING OPTIMIZATION

A Review of State Programs

by

E. D. Arnold, Jr.
Research Scientist

INTRODUCTION

On September 17, 1987, the Governor of Virginia announced that \$3.8 million from Virginia's Exxon oil overcharge refund would be used to undertake a statewide signal retiming project. The project is being conducted by the Virginia Department of Transportation (VDOT); however, the Department of Mines, Minerals and Energy is administering the funds through the State Energy Conservation Program. An interagency agreement was executed in April 1988.

During the period between the Governor's announcement and the signing of the agreement, the Virginia Transportation Research Council undertook a survey of signal timing optimization activities in other states. The primary purpose was to provide the VDOT with ideas on how to conduct Virginia's program. This report documents the findings from the survey.

SCOPE OF SURVEY

Time did not allow a comprehensive survey of states to identify all signal timing optimization activities underway. Rather, eight states known to conduct such activities, particularly those having well-known statewide programs, were contacted by telephone. Following is a list of states contacted and the names of their timing program:

1. California: Fuel Efficient Traffic Signal Management (FETSIM) Program
2. Florida: Gasoline Conservation Assistance Program (GASCAP) and State Traffic Signal Retiming Program (STSRP)
3. Illinois: Signal Coordination and Timing (SCAT) Program
4. Maryland: Statewide Traffic Signalization and Synchronization Program (STSSP)
5. Michigan: Traffic Signal Optimization Program (TSOP) and Traffic Signal Modernization Program (TSMP)
6. Missouri: TRANSYT-7F Program
7. North Carolina: Traffic Signal Management Program (TSMP)
8. Wisconsin: Wisconsin Fuel Efficient Transportation (FET) Program.

SUMMARY OF FINDINGS

This section summarizes the signal timing optimization activities in the eight states surveyed. A detailed discussion of each state's activities is provided in the appendices.

Types of Programs

Programs in the eight states can be categorized into four types, which are defined in the following.

1. A lead agency promotes the benefits of optimal signal timing, provides training in signal timing procedures, and provides technical assistance to localities that undertake signal timing projects. The actual work involved with developing and implementing timing plans is the responsibility of the locality. Florida's GASCAP is the most recognized program of this type. The lead agency is the University of Florida's Transportation Research Center, and its responsibilities are essentially as defined above. Missouri's TRANSYT-7F Program is similar in that the Division of Highway Safety installed the TRANSYT-7F software on a central facility's mainframe computer, provided workshops on using the software, and provided computer runs for localities wishing to avail themselves of the opportunity.
2. A grant program is established in which local agencies submit a formal application to undertake a timing project. The applications are reviewed and prioritized, and the awards are made according to established procedures. Grantees are required to attend scheduled training sessions on specified timing methodologies and to submit interim reports at specific stages in the process. The actual work involved with completing the timing project is the responsibility of the local agency; however, it can be performed with grant monies through a subcontract with a consultant. The prime example of this type of program is California's FETSIM Program, which is administered by CALTRANS. The Wisconsin FET Program, which is administered by the Transportation Policy Studies Institute of the University of Wisconsin at Madison, is a similar program.
3. A lead agency contracts with a consultant to perform signal timing activities throughout the state. The first phase may be a study to define signal needs, document the benefits and costs of a timing program, and recommend specific elements of a statewide program. The Illinois SCAT Program was developed in this manner, and the Illinois DOT (IDOT) is now contracting with consultants to carry out the actual timing procedures. A special position is being created within the IDOT to coordinate the program. The Michigan and the Florida DOTs have similar programs underway.
4. The state's transportation agency undertakes the timing program itself. All work involved with developing and implementing timing plans is performed by state personnel, usually from the

traffic engineering group. Additional personnel may or may not be hired. The prime example is North Carolina's TSMP, which is handled through the Signal Management Unit of the North Carolina DOT's Traffic Engineering Branch. The first program in North Carolina was administered through the University of North Carolina's Institute for Transportation Research and Education. The Office of Traffic of the State Highway Administration of the Maryland DOT has undertaken a similar program to time existing state-maintained signal systems.

Source of Funds

Most of the signal timing programs are funded in total or in part from oil overcharge money allocated to the state. The following programs are totally funded from oil money: California's FETSIM Program; Florida's GASCAP; North Carolina's TSMP; Wisconsin's FET Program; and Michigan's TSOP and TSMP. Many of these programs also utilize state funds in in-kind services. Florida's STSRP and Maryland's STSSP use both oil money and state money. Maryland is also using federal safety money. Illinois' SCAT Program is funded totally with state money, and Missouri's TRANSYT-7F Program used a grant from the National Comprehensive Transportation Systems Management Program.

Eligible Expenditures

Allowable program costs can be grouped into five categories as follows. Table 1 summarizes these costs by state program.

1. Services: promotion, training, technical assistance
2. Retiming: data collection, timing plan development, plan implementation
3. Retiming-related equipment: computer software, data collection equipment, computers, etc.
4. Minor equipment: time-based coordinators, add phasing, detectors, etc.
5. Major equipment: controllers, hard-wire interconnect, system masters, etc.

Table 1
Eligible Program Costs

Program	Services	Retiming	Equipment		
			Retiming-Related	Minor	Major
California FETSIM	X	X	X	X ¹	
Florida GASCAP	X	X ²			
Florida STSRP		X			
Illinois SCAT		X		X	
Maryland STSSP		X	X	X	X
Michigan TSOP		X		X	
Michigan TSMP				X	X
Missouri TRANSYT-7F	X		X ³		
North Carolina TSMP		X	X		
Wisconsin FET	X	X	X	X	X

¹Special demonstration projects.

²Special consultant subcontract with the Transportation Research Center.

³Participants given electronic turning movement counter.

Targeted Intersections

Intersections can be categorized as either isolated or in a signal system and as on either a state road or a local road. Most states recognize the greater payoffs associated with optimizing signal systems and thus target them in their timing programs. Because of limited resources, many states target the intersections on the state system of roadways. Following is a summary by program of targeted intersections:

1. California FETSIM Program: local roadway signal systems
2. Florida GASCAP: none
3. Florida STSRP: state roadway signal systems
4. Illinois SCAT: state roadway signal systems
5. Maryland STSSP: state roadway signal systems
6. Michigan TSOP: local roadway signal systems
7. Michigan TSMP: local roadway signal systems
8. Missouri TRANSYT-7F: local and state roadway signal systems
9. North Carolina TSMP - Program 1: local and state roadway isolated signals
Program 2: local and state roadway signal systems
10. Wisconsin FET: local roadway signal systems.

Evaluation Procedures

Most states have performed evaluations or require that the retiming projects be evaluated as to fuel savings and improved operations. Data for the evaluations can come from either before and after operational studies or from computer software output. Some programs rely solely on computer-generated statistics; however, most require or encourage actual before and after data collection at a sample of the intersections. California's Institute of Transportation Studies at Berkeley concluded from a controlled experiment using an instrumented vehicle that the TRANSYT software produces reasonably accurate estimates of savings.

Results

Several of the states have documented the fuel savings, operational improvements, and costs of their programs. Key statistics are summarized in the following sections; more in-depth evaluations are provided in the appendices.

California FETSIM (first three years)

- 3,172 intersections retimed
- \$231.6 million in total benefits
- \$3.973 million in total costs
- Benefit/cost (B/C) ratio = 58:1
- \$980 retiming cost per intersection

Florida GASCAP

- 83 intersections retimed

Florida STSRP

- 8,000 gallons of fuel saved annually per intersection
- \$900 to \$1,200 retiming cost per intersection

Missouri TRANSYT-7F

- 161 intersections retimed
- \$2.813 million in annual benefits
- \$87,300 in capital recovery annual costs
- B/C ratio = 32:1
- \$513 optimization cost per intersection

North Carolina TSMP (first program)

- 980 intersections returned
- 12,400 gallons of fuel saved annually per intersection
- \$66 million in total benefits
- \$460,200 in total costs
- B/C ratio = 143:1
- \$470 retiming cost per intersection

1234

APPENDIX A

State: California

Name of Program: Fuel Efficient Traffic Signal Management (FETSIM)
Program

Overview: In the early 1980s the California Energy Commission (CEC) pursued policies and programs to increase efficiency in the state's use of liquid fuels. Based on demonstration projects in Los Angeles and Garden Grove and a survey of local traffic agencies (which are responsible for about 18,500 of the state's 22,500 signals), the CEC implemented the FETSIM grant program in January 1983. The first year was funded with \$2.4 million from the state legislature. In late 1983 the program was turned over to CALTRANS, and four additional years were funded with Petroleum Violation Escrow Account (PVEA) funds. Total 5-year expenditures were \$7.3 million, which can be divided into five categories: \$5.37 million directly to local agencies, \$0.865 million for technical assistance, \$0.355 million for training, \$0.38 million for research and evaluation, and \$0.33 million for state administration. In September 1986 an additional \$7.5 million from PVEA funds were authorized over a 5-year period for the FETSIM program. A sixth year of the program began in January 1988.

The key element of the FETSIM Program is a grant to a local agency for a retiming project. The project must have a minimum number of signalized intersections that can be operated as a coordinated system. Grantees are "walked through" a 13-month project in which they are trained in the use of TRANSYT and are expected to complete certain basic tasks. The training is provided by the Institute of Transportation Studies (ITS) at Berkeley and consists of four workshops. Technical assistance is provided by both ITS and the Southern California Association of Governments (SCAG). The FETSIM Program conducted three equipment/retiming demonstration projects during the 1987 grant cycle and have six in the 1988 program. Funding of minor equipment upgrades is dependent on local interest and the demand for funding in the regular FETSIM retiming program.

Program Details: The sixth-year grant application manual was distributed in July 1987. The following sections give specific details set forth in the manual. (The details of the earlier years' programs may have varied slightly.)

Administration: The FETSIM Program is funded and managed through CALTRANS' Division of Transportation Operations and Toll Bridges. CALTRANS is assisted by two agencies: ITS provides training statewide and technical assistance to Northern California grant jurisdictions and SCAG provides technical assistance to Southern California grant jurisdictions. Localities are encouraged to conduct the project "in-house"; however, consultants may be used.

Program Training: One of the program's major objectives is to train local engineers in the use of signal timing computer tools; accordingly, grantees are required to send local staff to the following workshops.

1. Orientation (2 days)
 - basic TRANSYT principles
 - data collection requirements
 - coding input to TRANSYT
 - interpreting TRANSYT output
2. Calibration (1 day)
 - objectives of calibration
 - methods of calibration
3. Implementation (2 days)
 - signal optimization
 - timing implementation
 - before and after studies
 - evaluation of results
4. User (1 day)
 - local presentation of experience and results

Project Tasks/Products: Grantees are required to complete basic project tasks and deliver specific products by certain dates. If an agency falls behind schedule, CALTRANS will send a 30-day notice and the grant will be cancelled if the product is not submitted. Specific products include a link/node diagram, data reduction sheets, calibrated simulation runs/field calibration data, simulation runs of fine-tuned field plans, and a final report. Training and submission of products follow a specific schedule over a 13-month period.

Local Agency Costs/Subcontracts: A local match of 25%, unless otherwise justified, is required. The 25% can be in-kind services of local staff to complete the project work and/or monitor the work of a consultant, or it can be actual funds for paying a consultant. Grantees are permitted to purchase signal timing computer software packages and other low-cost items (such as data collection equipment) that enhance overall project objectives. These items are considered on a case-by-case basis. Payment of the state's share is made on a cost-reimbursement basis throughout the project, dependent on submittal of the products. Payments for each product do not exceed a specified percentage of the grant, unless prior approval is received, and 10% of each payment is withheld until completion of the final report. All consultant proposals and contracts must be approved by CALTRANS.

Hardware/Retiming Demonstration Projects: Limited funds are available for the purchase and installation of minor equipment and retiming. These projects target local jurisdictions that have not participated in the FETSIM Program because their signals lacked coordination equipment. In general, the equipment must either provide for coordination of a previously uncoordinated group of signals or add signals to a currently coordinated system.

Selection Criteria: A selection committee reviews all applications for the following:

- appropriateness and level of effort of local personnel
- suitability of project area to program objectives
- reasonableness of project costs/local match
- project area traffic volumes and patterns.

Results: During the first five years, more than 5,200 signalized intersections were retimed. A total of 140 grants ranging from \$5,700 to \$288,000, with a median of \$27,000, were awarded. A total of 93 local jurisdictions participated. The number of intersections in a project ranged from 7 to 267, with a median of 25. The majority of the projects consisted of actuated signals in arterial systems. Because of projects involving large pretimed grid systems, however, the actual number of pretimed and actuated signals retimed were about the same.

The 1988 program year has 28 grants totalling \$1.3 million and 1,018 intersections.

During the first three years of the program, only 20% of the projects were completed in-house. During the last two years, however, approximately 45% were completed solely in-house. These figures reflect the increasing technical abilities of local staffs, advancements in ease of use of TRANSYT, and the increasing emphasis on long-term maintenance of signal timing by local agencies.

Program costs and benefits for the first three years are summarized in an excerpt from an ITS publication (see Figure CA-1).

Evaluation Procedures: The evaluation is based on TRANSYT output; however, actual field verification with before and after studies is encouraged. Based on comparisons of TRANSYT output with about 20 before and after studies conducted by grantees and a controlled experiment in Berkeley using an instrumented vehicle, it was concluded that TRANSYT output is reasonably accurate. Specifically, TRANSYT overestimates benefits by 1% to 4%.

- References:
1. Macaluso, R. California's fuel efficient traffic signal management program. Paper read at the ITE Annual Meeting. 1987.
 2. FETSIM Grant Program Application Manual, July 1987.
 3. Three ITS reports (two on evaluation and one on the future of FETSIM).
 4. Two CEC/ITS public relations reports on the results of FETSIM.
 5. The city's Request For Proposals (RFP) for a consultant to conduct a FETSIM project.
 6. FETSIM Action Plan by the CEC.
 7. Miscellaneous articles.

TRANSPORTATION BENEFITS

Sixty-two local agencies retimed 3,172 signals during the three funding cycles of the FETSIM Program. Based on the TRANSYT model and actual field tests, stops were reduced by 16 percent, delays were reduced by 15 percent, travel time was cut by 7.2 percent, and fuel use declined by 8.6 percent. These results produce annual savings of approximately 20.1 million gallons of fuel. At an average fuel cost of \$1.15 to \$1.20 a gallon, those savings mean nearly \$24.1 million a year to California drivers. Using the American Association of State Highway and Transportation Officials' figures for value of time and the costs of vehicular wear and tear, an additional \$53.1 million is being saved by motorists each year.

Benefits from improved signal timings usually continue for two to five years, depending on the rate of travel increases and growth and development in each area. At an average of three years of benefits for each program cycle, the three cycles together will save \$72.3 million in fuel costs plus \$67.7 million in travel time and \$91.6 million in vehicle wear and tear. Total savings of \$231.6 million can be compared to total costs of \$4 million, for a benefit-cost ratio of 58 to 1. This benefit-cost ratio makes the FETSIM Program one of the most effective the State of California has ever offered.

OTHER BENEFITS

Direct benefits to motorists from the Fuel-Efficient Traffic Signal Management Program are obvious. But other important benefits are also produced. One important result of reduced stops and delays at traffic signals is a substantial decrease in air pollutant emissions—a significant bonus for California cities. Communities also gain

from improvements in traffic safety which result from smoother traffic flows. Bus operators and their riders benefit from better signal timing, since operating costs are reduced and average speeds improve. Finally, local agencies gain from the strengthened professional skills of participating staff members, as well as from the enhanced data base on local traffic conditions.

Program Costs

	1983	1984	1985	Three Year Total
Number of participants*	41	22	18	81
Number of signals retimed	1,535	937	700	3,172
Average cost per signal†	\$1,037	\$921	\$935	\$980
Total grants to cities	\$1,592,000	\$863,000	\$654,000	\$3,109,000
Costs of training, technical assistance, research, and evaluation	\$470,000	\$203,000	\$191,000	\$864,000
Total costs	\$2,062,000	\$1,066,000	\$845,000	\$3,973,000

*Some local jurisdictions participated in more than one grant cycle: a total of 62 separate jurisdictions have participated.

†Actual costs when available; otherwise grant awards. Contributions of local jurisdictions not included (average 5% of grant amounts).

Figure CA-1.

RESPONSE TO THE PROGRAM

Participants' responses to the Fuel-Efficient Traffic Signal Management Program have been overwhelmingly positive. In follow-up surveys, local agency personnel have consistently praised the program's design and expressed satisfaction with the results they obtained. One measure of success is the number of local agencies that have participated for a second or third time in order to extend the benefits of improved signal timing to other areas of their communities.

Some local agencies did experience problems. In a few cases, signal equipment was in serious need of repair, or turned out to be incapable of handling coordinated timing plans. A few other cities lost staff during the study and fell behind the program schedule. In a handful of cities, data problems hindered the development of optimal signal timings. Most of the agencies, however, were able to correct these problems and obtain good results.

User Benefits

Annual Benefits	1983	1984	1985	Three Year Total
	<i>(in millions of dollars)</i>			
Savings in fuel	12.80	6.70	4.60	24.10
Savings in vehicle wear and tear due to reduced delays	0.80	0.40	0.25	1.45
fewer stops	16.30	7.70	5.10	29.10
Savings in time due to reduced delays	12.40	6.20	3.95	22.55
Total annual benefits	42.30	21.00	13.90	77.20
Total assuming benefits continue an average of three years	126.90	63.00	41.70	231.60
Three year benefit-to-cost ratio	60:1	57:1	49:1	58:1

Figure CA-1, continued.

APPENDIX B

State: Florida

Name of Program: Gasoline Conservation Assistance Program (GASCAP) and State Traffic Signal Retiming Program (STSRP)

Overview: There are two signal timing programs underway in Florida. Each is funded in total or in part through the oil company overcharge refund program, which is administered by the Governor's Energy Office.

1. A sum of \$300,000 in oil money was established for GASCAP for local transportation agencies. The grant was awarded to the University of Florida's Transportation Research Center (TRC), and the program began in February 1984 and ended on June 30, 1987. The TRC assisted local agencies by:
 - (a) preparing project development guidelines and implementation packages to be used in initiating and carrying out traffic signal improvement projects
 - (b) developing promotional presentations to expose local agencies to signal timing methods
 - (c) providing training in the use of state-of-the-art technology in the analysis of traffic operations and the optimization of traffic signal timing
 - (d) providing implementation support through technical assistance, direct access to the Northeast Regional Data Center's computer system, or make computer runs and limited data coding and data entry
 - (e) conducting program evaluation.

Some of the grant funds were available for consultant assistance (subcontract with TRC) directly to localities for data collection, reduction, and coding; and interpretation of improved timing plans. All local expenses were paid for by the participating agency.

Based on an evaluation of the program, an expanded GASCAP II was initiated in February 1988 by the TRC. The project is a 2-year program requiring \$300,000 in oil money. The program continues the support to localities and extends assistance to the Florida DOT's (FDOT) retiming projects by conducting workshops for project engineers and establishing consultant review procedures. Further, the TRC provides support for the FDOT's Traffic Operations Computer Package, develops procedures for problem identification and evaluation, and establishes a statewide UTCS monitoring facility.

2. A second program, the STSRP, began in FY85 with a \$750,000 grant to the FDOT. A total of \$1.2 million was spent in FY86. Both expenditures were from oil overcharge money. In FY87 the FDOT allocated

about \$1 million, and another \$1 million is allocated for FY88, of which about \$435,000 are from oil monies. This program is administered through the Office of Traffic Operations; however, all work is performed by consultants. The program is targeted to the 5,000 (of 11,000 statewide) signals on the state highway system. For one year of the program, the consultant was required to (1) collect data, (2) develop traffic control timing patterns, (3) implement the new timing patterns, and (4) perform a before and after evaluation. The after evaluation involves travel time delay studies for a sample of 20% of the retimed intersections.

Details of GASCAP I: Following is a summary of GASCAP I, which ended on June 30, 1987:

Promotional Efforts:

1. Eight newsletters were distributed.
2. The following documents were prepared:
 - a. program description
 - b. participation manual
 - c. project manual
 - d. data collection manual
 - e. evaluation manual
 - f. computer services user's manual.
3. Eighteen Traffic Signal Timing Improvement Seminars were held.
4. A Technical Session on GASCAP was presented at two Florida Section ITE (FSITE) meetings, and at two local chapter meetings of the American Public Works Association. Booths were set up at two FSITE annual meetings.

Training Efforts: In addition to the 18 seminars, GASCAP sponsored the following:

1. an Arterial Analysis Package training course
2. several Microcomputer workshops
3. a special GASCAP/McTrans workshop
4. six workshops entitled "Signal Timing Tools for the '80's"
5. development and implementation (one pilot presented) for a course entitled "Implementation of Traffic Signal Timing Plans."

Technical Assistance Efforts:

1. GASCAP projects: A total of seven cities and counties participated. Nine systems consisting of 72 signals and 11 isolated signalized intersections were retimed.
2. Twenty-five agencies had computer accounts.

Conclusions: The primary conclusion is that there is a great deal of interest in traffic signal retiming at the local level, but interest alone does not accomplish much. Even in the cases where GASCAP could assist in data collection, local agencies were hard pressed to devote resources to this area.

The following specific conclusions were drawn:

1. Promotion of traffic signal timing needs should be directed to decision makers.
2. Local transportation agencies are interested in traffic signal retiming but lack the funds or personnel resources to be very active, except in the largest communities.
3. Coordination between different agencies such as cities and counties who maintain signals and signal timing and between local agencies and the FDOT is not always adequate to ensure efficient signal timing management.
4. The availability of signal timing software for microcomputers and the increasing recognition that transportation agencies should have access to micros should improve the likelihood that smaller agencies will be more active in signal timing.
5. Smaller local agencies are generally not well staffed with people qualified to design signal timing or maintain the signals themselves.
6. Based on our tangential exposure to the FDOT's retiming program, it is clear that many consultants are not adequately qualified to use signal timing models.
7. There is presently no way to identify problem locations adequately where retiming is more urgent than others.

- References:
1. Evaluation report on GASCAP.
 2. Various scopes of work for consultant services.
 3. Various proposals for signal-related projects.

APPENDIX C

State: Illinois

Name of Program: Signal Coordination and Timing (SCAT) Program

Overview: In late 1985 the IDOT, Bureau of Traffic, initiated the SCAT Program by hiring Barton-Aschman Associates, Inc. (BAA) for \$225,285 to undertake a study. The program, and thus BAA's study, had the objectives of determining the number and characteristics of traffic signals in the state; demonstrating benefits of improved signal timing; estimating costs, needs, opportunities, and benefits of a statewide traffic signal improvement program; and developing a statewide program for improvements. The goal of the SCAT Program is to provide systematic improvement to traffic signal operations on a statewide basis. The primary focus is the development of optimal signal timing plans. A final report was issued in September 1987, and continuation of the program as recommended by BAA is underway.

A total of \$600,000 in state money is allocated to the program for calendar year 1988. Additional state money will be used to hire a full-time program coordinator to work in the IDOT Bureau of Traffic. This effort is in process; however, it has been held up by typical state personnel issues. Meanwhile, a Bureau of Traffic employee is serving as coordinator. The actual work will be performed by a consultant. Two contracts for signal timing optimization are in process: one for District 1, which contains Chicago, and one for Districts 2 through 9. The former contract is being administered by District 1, and the latter by the Central Office Bureau of Traffic. The general procedure is to send out an abbreviated RFP (basically a scope of work), accept and review consultant proposals on how to conduct the project, select a consultant, and then negotiate final details and costs. Consultant selection is underway, and letters to solicit candidate intersections have been sent to the Districts. Because of the limited amount of money, only signals on the state system are eligible this year. Priority will be given to updating signal systems in recently developed areas. Once a district project is selected, district personnel will work directly with the consultant to obtain engineering services for data collection, data analysis, implementation, and evaluation. Minor equipment changes may also be funded, e.g., addition of time-based coordinators (TBCs) to interconnect adjacent isolated intersections or the addition or deletion of phases. The initial list of candidate intersections is due March 18, 1988.

Details of the Barton-Aschman Study: The study has four main sections, corresponding to the four objectives mentioned earlier; pertinent findings from each section follow:

1. Survey: There are approximately 6,900 signals in Illinois, 4,500 of which are on the state system. Chicago has 38% of the signals; another 31% are located in IDOT District 1 but outside Chicago. Of the 4,300 signals outside Chicago, 80% are on the state system.

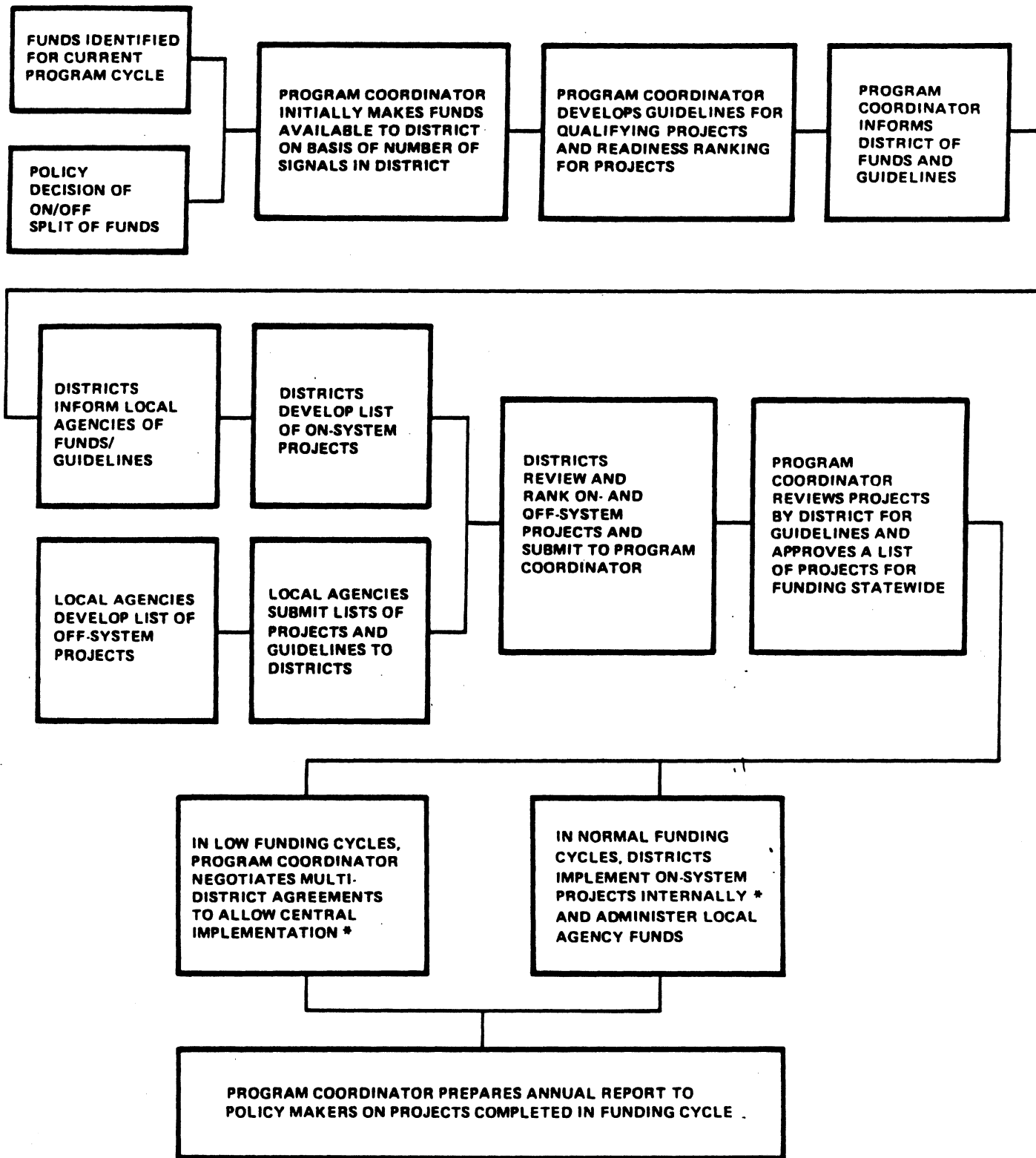
2. Opportunities, costs, and benefits: Based on an expansion of a 5% stratified sample, the following opportunities for signal improvements were found: late-night flash, permissive left turn, exclusive left turn, multial with time clock, improved phasing, actuate, coordinate with other signals, improve timing for both isolated and system signals, and replace with 2-way stop. Estimates of B/C ratios for the most beneficial improvements were 63:1 for improved timing of isolated signals, 16:1 for late-night flash, 6:1 for coordination, 3:1 for improved timing of existing systems, and 2:1 for allowing permissive left turn.
3. Demonstrations: Operational improvements were developed at 21 isolated intersections and for seven signal systems. TRANSYT and SIGNAL 85 were used to model the systems and isolated intersections, respectively. While the intent was to implement the recommended improvements, very few have been implemented to date. Accordingly, there are no evaluations to report.
4. Program: The recommended administration of the program has essentially been accepted by IDOT. A copy of the flowchart is shown in Figure IL-1.

Consultant Services: Details of the engineering services to be provided by the consultant to the districts are attached as Figure IL-2. The contract is in final negotiation; however, it will likely be on a per task cost basis.

Additional Information: The IDOT reports that it has gone to consultants because of a lack of manpower to perform the studies and optimizations. The decision to hire a consultant to conduct the initial study was based partly on the idea that administrators tend to believe and accept "outside" reports more so than "in-house" efforts.

Improvements to intersections on a state-system road inside cities and maintenance (including timing) are funded on a 50/50 basis. Some of the maintenance at state intersections is performed by local agencies if they have the capability. The costs are divided 50/50.

- References:
1. RFP for the BAA study.
 2. Key parts of the BAA contract.
 3. BAA's signal survey letter.
 4. BAA's initial report.
 5. RFP for calendar year 1988 timing work.
 6. Consultant agreements for calendar year 1988 (to be sent).
 7. Memos from the IDOT central office to districts regarding the SCAT '88 program.



* IMPLEMENTATION COULD BE ACCOMPLISHED VIA CENTRAL STAFF, DISTRICT STAFF, LOCAL AGENCY STAFF, CONSULTANTS, AND/OR A COMBINATION OF THE ABOVE.

Figure 2
FLOWCHART OF SCAT PROGRAM ADMINISTRATION FOR A SINGLE FUNDING CYCLE

Figure IL-1.

20. Traffic Signal Coordination and Timing (SCAT), Bureau of Traffic, Statewide (Exclusive of District 1).

The consultant who is selected for this project is scheduled to attend a negotiation meeting on January 22, 1988 at 10:00 a.m. at the Central Bureau of Traffic office in Springfield.

Engineering services are required to ensure signal optimization is achieved at various isolated traffic signal and traffic signal system locations statewide (exclusive of District 1). The project will include accomplishment of one or more of the following tasks for each selected location during calendar year 1988:

1. Data Collection - Field collection of traffic counts, turning movements, signal phasings, signal timings, equipment inventory, and other data needed to quantify existing operating conditions and determine signal optimization alternatives.
2. Data Analysis - Appropriate computer models such as SIGNAL, TRANSYT, and PASSER II-84 will be run on the data base for each of the selected locations. Recommendations for optimal signal operation plans will be generated utilizing the existing signal equipment and also with minor recommended equipment enhancements. Engineering judgment will be used to select the final plan to be recommended for implementation.
3. Implementation -The approved optimization plan will be placed in operation and any necessary fine-tuning adjustments will be made.
4. Evaluation - A study of the effectiveness of the optimization plan will be conducted. Benefits will be estimated in terms of travel delay reductions, fuel savings, and reduction in carbon monoxide emissions.

Recommendations for further enhancements to the optimization plan and/or equipment modifications may be requested for locations where the operation is still unsatisfactory.

The Department will furnish manuals, plans, or other available information the consultant feels would be helpful.

Firms must be prequalified in traffic signals and furnish a list of projects they have done involving traffic signal systems.

Exhibit A for this project must include a listing of the following key personnel, along with copies of their resumes':

Figure IL-2.

APPENDIX D

State: Maryland

Name of Program: Statewide Traffic Signalization and Synchronization Program (STSSP)

Overview: The Office of Traffic of the State Highway Administration of the Maryland DOT has had underway for several years a program to upgrade and retune the 95 existing signal systems on state highways. A June 1987 document reported a 5-year program at a cost of \$4.7 million. Seventy-two of the signal systems have three or more intersections, and plans are to interconnect these with telemetry cable, install sampling stations, and place monitors in the district offices and central office in order to operate them as traffic responsive systems. The other 23 systems will remain time-based coordinated. The Bureau of Traffic Projects personnel are using TRANSYT-7F to obtain the retimings. They also plan to equip 1,000 isolated intersections with monitors so that they can be monitored from the district and central offices. The primary source of funding is the Traffic Control Fund 85, which is 100% state money. Funds from a federal safety grant are also used at high hazard locations, as well as a grant of approximately \$102,000 from Maryland's Energy Overcharge Restitution Fund. The energy money is being used to purchase monitors, software, telemetry interconnection, and salaries. A second energy fund grant of \$48,000 is in the works, which will be used for telemetry interconnection. All work is being handled by Maryland DOT personnel.

- References:
1. Brief report covering the Energy Fund.
 2. Brief report on the signalization program.

APPENDIX E

State: Michigan

Name of Program: Traffic Signal Optimization Program (TSOP) and
Traffic Signal Modernization Program (TSMP)

Overview: The Traffic and Safety Division of the Michigan DOT (MDOT) has two programs underway that utilize PVEA funds and concern signal timing. The first was initiated in 1985 when a grant of \$748,944 from Amoco money was awarded. An RFP was distributed in late 1984, and a \$500,000 contract was awarded to a private consultant to develop timing plans and recommend equipment needs in 25 cities and towns with 1,087 signalized intersections (of approximately 5,000 signals in 615 local jurisdictions). The consultant has completed the study; however, no documented final report was required. The MDOT will approach these cities and towns in the near future to obtain concurrence with the consultant's recommendations. After obtaining concurrence, the remaining grant money will be spent on minor equipment needs and the timings installed in conjunction with the city or town. Because of manpower shortages, the MDOT has not yet undertaken this implementation.

Based primarily on the findings of the first program's consultant study, a second 2-year program with \$3.25 million from AmocoII, Vickers, et al. has just been approved. The purpose is to provide and install the necessary traffic signal equipment to support the implementation of optimized traffic signal timing in 15 cities. Funding will be used to pay consultants to prepare engineering plans and other documents necessary for contracting the installation of the required on-street equipment. Funding will also be used for the direct purchase of equipment, which will be given directly to the cities capable of installing it. Contracts for installation will also be paid for if the city cannot install the equipment itself.

Timing Procedures: No information was received on the consultant's methodology.

Evaluations: No evaluations have taken place; however, estimates at the 900 intersections located in the 15 cities involved in the second program are 9.9 million gallons of fuel saved annually at a savings of \$8.415 million. The resulting estimated B/C ratio is 2:58.

References:

1. The RFP for the first program.
2. Progress report for the first program.
3. Proposal for the second program.

APPENDIX F

State: Missouri

Name of Program: TRANSYT-7F Program

Overview: The Missouri Division of Highway Safety received a \$100,000 grant from the National Comprehensive Transportation Systems Management Program to demonstrate to Missouri's traffic engineers the benefits attainable through optimizing traffic signal timing plans. The project was designed to install the TRANSYT-7F computerized program on a central facility's mainframe and make runs for communities throughout the state. A preliminary survey found about 1,600 local signalized intersections not maintained by the state. Three 4-day workshops on TRANSYT-7F were presented, and cities participating in the program were given a Timelapse electronic turning movement counter.

Results: Eight cities participated in the program, and 161 intersections were optimized. All intersections were in hard wire interconnected systems, and some were maintained by the state. One city installed additional signals and interconnect. Average reductions in performance indicators were 21% in delay time, 12% in fuel savings, and 16% in stops. The grant of \$100,000 was expended as follows: \$4,937 for training, \$17,494 for equipment, \$5,351 for computer run time, and \$72,218 for project coordination. A total of \$206,419 of matching money was expended: \$78,925 for city personnel or consultant services for data collection, data reduction, installation, etc.; \$118,069 for equipment; and \$9,425 for state coordination.

The cost for the actual optimization (excluding state coordination and signal equipment) was \$82,533, or \$513 per intersection. Annual benefits based on output from TRANSYT-7F were \$2,813,200. The capital recovery annual cost was \$87,296, resulting in a B/C ratio of 32:1.

Reference: 1. Draft evaluation report.

APPENDIX G

State: North Carolina

Name of Program: Traffic Signal Management Program (TSMP)

Overview: Traffic signal retiming has been underway by the NCDOT since the early 1980s with state funds. There is a permanent three-person Signal Systems Squad (SSS) in the Signals Management Unit of the NCDOT Traffic Engineering Branch. The SSS did mostly system timings. The first PVEA-funded program (Amoco money) had the objectives of providing personnel and financial support for optimizing 750 traffic signal installations and of providing sufficient evidence of the program's benefits so that continuation might be considered. The Energy Division funded the 29-month (6/12/85-11/30/87) program, and the University of North Carolina's Institute for Transportation Research and Education (ITRE) had overall administrative responsibility. Six trainees--three graduate engineers and three graduate electronics or electromechanical technicians--were hired in July 1985 by ITRE and joined the SSS to form a new Statewide Signal Optimization Squad (SSOS). Office space and supplies were provided by the state government in a state office building in Raleigh. The trainees received six months of comprehensive on-the-job training and attended Georgia Tech's two signal short courses. The NCDOT's Signals Management Unit developed two manuals on signal retiming procedures and retiming evaluation using TRANSYT-7F4, respectively, to assist in the training. The general procedure was for three teams to travel throughout the state, collect the necessary data, establish the optimum timing, and make minor repairs. All but 14 of the 980 intersections timed (of 4,600 statewide) were isolated. The total cost was \$460,235.

A second program was implemented on December 1, 1987, with a \$3 million grant from the Energy Office using Exxon overcharge monies. Ten people will be hired to form the SSOS. The program is basically being conducted the same as the first except the ITRE is no longer participating. The contract is between the Energy Office and NCDOT. All costs, including salaries, are charged to a work order, and the Energy Office is billed per those work orders. The contract specifies that 1,240 intersections be retimed. Emphasis is to be placed on signal systems in recognition of the greater payoff. A system signal counts as five toward the 1,240 goal.

Results: A summary of the first program's results follows:

1. Signals timed: 980 (14 of which were in systems).
2. Total costs: \$460,235 or \$470/signal.
3. Benefits (annual):
 - 12,163,094 gallons of fuel saved; 12,411 gallons/signal
 - \$11,668,854 saved in fuel costs; \$11,907 saved in fuel costs/signal

- B/C ratio for fuel only = 25:1
- \$45,095,270 saved in operating costs (fuel, delays, and stops);
\$46,016 saved in operating costs/signal
- B/C ratio for operating costs = 98:1

4. Benefits (accumulated over the 29 months):

- 17,770,560 gallons of fuel saved
- \$16,118,510 saved in fuel costs
- \$66,003,610 saved in operating costs
- Project B/C ratio for fuel only = 35:1
- Project B/C ratio for operating costs = 143:1

Timing Procedures: 1) TRANSYT-7F4 was used where a computer was available in the field; otherwise, the critical-lane method was used to determine optimum timing. In the latter case, the timing was calculated later using TRANSYT-7F4 to verify the field timing and, in a few cases, the timing in the field was changed.

2) Existing traffic data and timing were used to determine the level of service (LOS). This computer-determined LOS was compared with the observed traffic flow conditions, and appropriate adjustments were made to bring existing data and computed levels of service into agreement with the observed conditions (usually by adjusting saturation flow rates).

3) Timings were designed for the annual afternoon peak four Fridays for a 4- to 5-year future forecast. These design-year volumes were applied in either TRANSYT-7F4 or the critical lane method and the resulting timing installed in the field. Fine tuning field adjustments were then made as necessary.

Evaluation Procedures: Existing measures of effectiveness (MOEs) were calculated using TRANSYT-7F4 and compared with the same MOEs calculated from the optimum timing. The differences between the two provided estimates of savings in fuel consumption, delays, and stops. These procedures, which included both peak and off-peak hours, are explained in more detail in the information available.

Additional Information: Of the 980 intersections retimed, 258 (26%) fell into the "break-even" or "optimized timing equals existing timing" category.

- References:
1. Excerpts from ITRE's progress reports.
 2. TRB paper on TSMP.
 3. ITE article on TSMP.
 4. Miscellaneous excerpts from Exxon programs.
 5. NCDOT's training manuals.

APPENDIX H

State: Wisconsin

Name of Program: Wisconsin Fuel Efficient Transportation (FET) Program

Overview: The Department of Civil and Environmental Engineering at the University of Wisconsin at Madison (UW-Madison) received a grant of \$990,000 in PVEA funds from the State Energy Office in spring 1987 to help localities improve traffic signal timing and thus reduce fuel consumption. The FET Program is administered by the Transportation Policy Studies Institute (TPSI) of UW-Madison. The goal of the FET Program is to assist local engineers, via locality grant applications, to decrease fuel consumption through the development of computer-optimized signal timing plans and the purchase of hardware required to implement these timing plans. Participating communities identify a network of traffic signals (the emphasis is on systems) and undertake a signal timing optimization project including data collection, timing plan development using TRANSYT or AAP, implementation, and field evaluation. Participants conduct a 1-year structured series of tasks leading to a final report. The hardware grants are available in two stages: an initial basic grant of \$1,000 per intersection and an optional supplemental allocation based on the cost-effectiveness of the proposed hardware improvements in saving fuel. A \$1,000 in-kind match per intersection is assumed from local staff time. Training and technical assistance for localities is to be provided by UW-Madison.

Program Details: The Grant Application Manual was distributed in June 1987, and FET grants totalling \$518,000 were awarded in August to 24 localities. The total grant of \$990,000 consists of \$246,700 for technical assistance and training, \$518,000 in initial basic grants, and \$225,300 for the optional supplemental hardware grants.

Grantees are required to attend a series of 4 workshops which will walk them through a signal timing project. The workshops are as follows:

- Orientation (2 days, October 1987)
- Calibration (1 day, January 1988)
- Implementation (2 days, May 1988)
- User (1 day, September 1988 or April 1989 for supplemental grantees).

Each locality must complete basic project tasks by specified dates, and a failure to deliver can result in a termination of the grant. Training and tasks will relate to using TRANSYT or AAP in the case of simple systems or isolated intersections.

In general, eligible hardware can be divided into the following categories:

- coordination hardware and the microcomputers needed to run the timing software

- local intersection hardware, including controllers, additional signal heads, and detectors
- computerized signal system masters.

Localities may contract with a consultant to perform the work; however, all contracts must be approved by TPSI.

The program is based on cost reimbursement, and 25% of each periodic payment is withheld until completion of the final report.

Additional Information: A survey of traffic signal equipment and interest in equipment improvements was undertaken by TPSI at the outset of the program.

The FET Program applied for (and apparently received) a Highway Safety Project Grant from the Wisconsin DOT Office for Highway Safety to cover participants' travel expenses and cost for training materials at the required workshops.

Evaluations: The program is currently underway and no evaluations have been conducted.

- References:
1. FET Program Grant Application Manual.
 2. Three newsletters.
 3. Survey questionnaire.